TRANSACTIONS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY.

ARTICLE I.

THE MORPHOLOGY OF THE SKULL OF THE PELYCOSAURIAN GENUS DIMETRODON.

[Plates 1–7.]

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(Read October 7, 1904.)

The following description is based on four skulls in the collection of the University of Chicago, bearing the numbers 1, 114, 1001 and 1002, in the collection of vertebrate fossils of that University. All four of the skulls were discovered and collected by the author of this paper, the first two in the summer of 1896 and the last two in the summer of 1903. All are from practically the same horizon, the Permian beds of Texas, in Archer and Baylor Counties. Numbers 1 and 114 have already been pretty fully described by the author (Baur and Case, '99, '03), and only such portions are here redescribed as are necessary to supplement the material afforded by specimens 1001 and 1002. The last two consist of singularly perfect skulls, showing the complete anatomy of the temporal arches, a region which, by reason of its fragility, is almost always destroyed in the process of fossilization. The two skulls were accompanied by considerable portions of the skeleton in both cases, but were preserved in a very different manner. Number 1001 was discovered in a soft, friable shale, carrying much gypsum and many impressions of ferns, with a considerable quantity of lignite. The nature of the matrix caused the bones to be badly broken and in some parts rotted by the gypsum, but all were preserved in place, and the skull and lower jaws were continuous with the skeleton. The processes of collection and preparation have been very tedious, but when once the bones were joined they could be cleaned from the

clay by simple washing with a soft sponge, so that all the most minute details of structure and sculpture are clearly made out.

Specimen No. 1002 was preserved in a compact red clay, and the bones were covered with a hard scale of calcareous material, which was removed with comparative ease, leaving the bones hard and perfect. This skull is unique in the perfection of its preservation, the only portions missing being the temporal arches, in part, of the left side and the median portion of the epipterygoids. The skull lay on its side, and all the bones are joined in their natural relations. The whole skull has been crushed slightly from the sides, so that it is seemingly more narrow than it really is. The bones of the top of the skull have been slightly broken and the palate has been pushed slightly downward, but on the whole the skull has been so little changed from its natural condition in life that it is easily restored.

The four specimens are evidently of the same genus, *Dimetrodon*, of the *Pelycosauria* but do not belong to the same species; it is impossible to state their specific position exactly in the present state of our knowledge, but the specimen numbered 1 has been described (Baur and Case, '99) as *Dimetrodon incisivus;* number 114 as *Dimetrodon* (*Embolophorous*) *dollovianus* (Case, '03); number 1001 is undetermined but stands very close to number 1; number 1002 is almost certainly *Dimetrodon gigas.* No attempt will be made in this paper to point out specific distinctions, the object being solely to give an accurate account of the skull of the genus *Dimetrodon* as an example of the skull of the *Pelycosauria* in general. The restored skull is made up almost entirely from the skull of *D. gigas* (No. 1002) and may be accepted as a very accurate account of the skull of that species, as so little has been used from other sources.

In the original descriptions of specimens 1 and 114 (Baur and Case, '99; Case,'03) an error was made in considering the articular region of the lower jaw as the articular region of the skull proper; this led to an unfortunate series of comparisons and speculations which must be in large part abandoned as based on false assumptions. Notable among these was direct comparison of the *Pelycosauria* with the *Theriodonts* of South Africa (*Cynognathus* and *Gomphognathus*); this error was due to the supposed depression of the quadrate bone and its almost complete disappearance under the suspensorial bones, a condition very close to that of the African forms; the demonstration that this condition is not found in the *Pelycosaurs* removes them from any possible connection with the *Theriodonts* though newly discovered structures place them, probably, rather nearer to the *Therocephalia* of Broom ('03). The error here cited has already been corrected in two papers (Case, '04, '04').

The discovery of the elevated condition of the quadrate region shows that the restoration of the skull previously published (Baur and Case, '99) was too short in the

posterior portion and that the orbit was much nearer to the middle of the skull. The elevated facial region while it is one of the most characteristic features of the skull was not carried to the extent figured by Cope in his restoration of the closely related genus *Naosaurus* ('92).

Below is a detailed description of the skull in which it will be seen that in most particulars it bears a striking likeness to the skull of *Sphenodon* so that in most parts the two can be compared directly.

The *quadrate*, Pl. V, fig. 1: This is a thin plate of bone of considerable vertical extent reaching nearly half the height of the posterior portion of the skull, but not reaching such a great antero-posterior length as the same bone in *Sphenodon.* The articular portion consists of two condyles elongate in the antero-posterior direction and with their main axes converging slightly as they advance so that all motion of the jaws was rigidly limited to the vertical plane. The outer condyle is the more slender and lies almost in the plane of the upper portion of the bone; posteriorly it extends beyond the main part of the bone as a prominent process with its upper face flattened into a sort of shelf to which is attached the lower end of the quadrato-jugal. The inner condyle is stouter and is offset from the body of the bone. The posterior edge of the quadrate is rounded and gives attachment through its length to the quadrato-jugal, but just above where the quadrato-jugal joins the upper surface of the inner condyle the two are separated by a good sized foramen, the *foramen quadratum.* This foramen serves as an important landmark in the skull; it is not present in the *Cotylosauria;* it is probably present in the primitive *Archosauria* (= *Diaptosauria*, Osborn) although it has been demonstrated only in the *Pelycosauria* and *Rhyncocephalia vera;* it is present in the *Theropodous Dinosaurs*, the *Icthyosaurs* and the *Phytosaurs;* it is absent in the *Crocodilia*, the *Pterosaurs* and the *Squamata.*

The posterior end of the pterygoid overlaps the quadrate on the inner side, the lower edge extends back almost to the posterior limit of the bone and is attached to the inner side of the inner condyle.

The *quadrato-jugal:* The quadrato-jugal occupies a relatively unimportant position in the skull. It is a very thin plate of bone, with its lower end and posterior edge attached to the quadrate as described above. The upper end becomes very sharp and is wedged in between the prosquamosal and squamosal and comes in contact with the parietal. It is separated from any contact with the jugal by the descending process of the prosquamosal, as described below, and in turn it separates the prosquamosal from the squamosal, thus occupying a unique position among the reptiles. The position of the quadrato-jugal is not anomalous, however, for if the upper end were withdrawn from contact with the parietal by shortening, the prosquamosal and

squamosal would come in contact, and a union of the two would produce the bone called squamosal or squamosal + prosquamosal in *Sphenodon*.

The *prosquamosal:* The prosquamosal has the position usually assigned to the quadrato-jugal; that is, it connects the jugal and the quadrate. It would have been taken for the quadrato-jugal in the present specimens if the presence of the *foramen quadratum* had not indicated the true position of the quadrato-jugal. (The significance of the position of the prosquamosal is discussed in the description of the temporal region below.) The prosquamosal joins the jugal in about the middle of the inferior temporal arch, the two bones narrowing somewhat as they approach, so the edges of the inferior arch are concave both above and below. Posteriorly the prosquamosal widens, so that it has an upper and lower process and the bone becomes roughly T-shaped. The lower three quarters of the posterior edge join the quadrato-jugal and the upper quarter joins the anterior edge of the posterior process of the postorbital to form the posterior edge of the superior temporal vacuity. There is a little doubt as to whether the prosquamosal joins the edge of the quadrato-jugal directly or passes under it, articulating with the lower surface, and finally articulates with the edge of the quadrate near the quadrato-jugal. The specimen No. 1002 seems to indicate the latter condition on one side.

The bones forming the edges of the superior temporal vacuity are approximated so the vacuity is very small.

In the crushed specimens the sides of the upper vacuity are very close together and it seems that they must have been so in life. The edges of the bones where they would meet are very thin and it is possible that they did meet over the vacuity in specimen 1001, although there could have been no articulation even in this case. It is impossible to say positively whether this is an appearing or a disappearing vacuity but the former seems to be the most probable from all considerations. In *Diopeus* the most primitive member of the *Clepsydropidæ*, the superior vacuity is very small or absent. In specimen 1001 there is a strong rugosity of the lower ends of the parietal which covers the vacuity but this I am inclined to regard as pathological.

From the foregoing it will be seen that so far from the quadrate region of the skull being depressed and approaching the *Theriodont* type with any relation to the development of the mammalian skull it is elevated and of the most primitive character and in connection with all the other specializations of the skeleton of the American *Pelycosauria* (*Clepsydropidæ*) indicates rather the approaching culmination of a side branch of the primitive stem than the true progress of the *Sauro-mammalian* mutation which was seemingly accomplished in Africa. It is not proven however, as Osborn suggests, that the *Gomphodontia* were descended from forms with primitively

a single arch (*Synapsida*) for the possible affinity of the *Pelycosauria* and *Therocephalia*, the last the acknowledged ancestors of the *Theriodonts*, shows that the ancestors of the two groups may have been common and have had two arches, at least potentially.

The determination of the composition of the temporal arches and the identification of the *foramen quadratum* in the *Pelycosauria* enables certain comparisons to be made that shed some light on the possible history of the development of the temporal region in general. Baur has claimed that the squamosal of *Sphenodon* is the united prosquamosal and squamosal of the *Lacertilia* and has cited the condition of *Saphæosaurus* to prove this; on the other hand the evidence of embryology is negative or even against this idea, for Howse and Swinnerton have shown that there is but a single center of ossification in the developing squamosal of *Sphenodon* ('93), a fact admitted by Baur ('94), and Parker has shown that there is but a single center of ossification for the squamosal of the *Crocodilia*.

In the specimens of *Dimetrodon* here described we have the most perfect example of the skull of the primitive *Archosauria* (= *Diaptosauria*, Osborn) known; it is unfortunate that the specimens should be of the most specialized members of the group but a comparison with a less perfect skull of a more generalized member of the same family, *Diopeus* (Case, '03') shows that the primitive condition has remained largely unaffected by minor changes. As shown in the figures, the prosquamosal of the *Pelycosauria* occupies the position of the quadrato-jugal in higher forms, *i. e.*, it connects the jugal and the quadrate region; it articulates with the postorbital above and the quadrato-jugal behind, and is separated from the squamosal by the union of the quadrato-jugal and the parietal. It is evident that the shortening of the quadrato-jugal and its withdrawal from contact with the parietal would permit the meeting and possible union of the squamosal and prosquamosal; if the two bones united it would produce the exact condition of the skull of *Sphenodon*, for all the other bones have the same relations in the two forms and the *Sphenodon* has a forward prolongation of the squamosal which is exactly the same in form and relations as the separate prosquamosal of the *Pelycosauria*. This with the separate condition of the two bones in *Saphæosaurus* and in the *Icthyosauria* would seem to establish the primitive freedom of the bones beyond question were it not for the antagonistic embryological evidence; because of this it seems best to present the case in full.

Concerning the region, Baur said ('94, p. 321): "Es handelt sich nun darum, zu zeigen, dass das squamosum von Sphenodon in der That aus 2 Elementen besteht. Der jüngste von 6 schädeln, den ich vor mir habe (Condylis-occipitalis-Præmax, 25 mm.) zeigt keine andeutung von 2 elementen; dagegen scheint bei Saphæosaurus (Sauranodon) aus dem lithographischen Schiefer von Cirin das squamosum durch 2

stücke vertreten zu sein." He then cites Lortet's description of the skull ('93) as incorrect, and Boulenger's remarks on Lortet's description ('93) to support his own contention as to the separate nature of the elements. Boulenger said "The bones described as the posterior portions of the parietals appear to be the supratemporals (=prosquamosals), distinct from the squamosals."

In the *Ichthyosaurs* the two bones are always separate.

In the *Dinosaurs, Phytosaurs, Crocodilia* and *Pterosaurs* there is one less element in the temporal complex; the absent bone belongs to the lower arch, and, judging from its relations, could be either the quadrato-jugal or the prosquamosal; that it is the latter is shown by the presence of the quadrate foramen, for it is hardly possible that such a fenestra as the quadrate foramen, carrying no vessels, should survive a series of changes involving the disappearance of the quadrato-jugal and the assumption of its position by the prosquamosal. If the above reasoning is correct the foramen quadratum assumes a considerable morphological importance, as it marks definitely the posterior bone of the lower arch as the quadrato-jugal. From a consideration of the position of the quadrato-jugal in the *Pelycosauria* and *Sphenodon* and a comparison with the position of the same bone in the *Crocodilia, Dinosauria* and *Pterosauria* it is easily seen that the forward growth of the quadrato-jugal to unite with the jugal may have pushed up the prosquamosal and excluded it from the lower arch. In the *Dinosauria* in general, and especially in the *Theropodous Dinosaurs*, which are the most primitive, and very similar in most points of skull structure to the *Pelycosaurs* (the *Theropodous Dinosaurs* are the only ones which possess the quadrate foramen), we find the same sort of an anterior process of the squamosal as occurs in *Sphenodon.* The steps seem perfect from one condition in the *Pelycosauria* to the other in the *Sphenodon* and *Theropodous Dinosaurs.*

In the *Dinosauria* where the quadrate foramen is missing, the *Sauropoda* and *Predentata*, the *Crocodilia* and *Pterosauria* it is safe to assume that the same bone has disappeared as in the forms where the steps can be traced.

Although the present specimens give no positive evidence concerning the disappearance of the lower arch in the *Squamata* it suggests very forcibly one thought. The foramen quadratum is in its inception in the *Pelycosauria* (it does not occur in the *Cotylosauria* or in the primitive Pelycosaurians, *Diopeus* (Case, '03') and is much larger in *Sphenodon*; it seems possible that the same process of fenestration which developed the superior and inferior temporal vacuities may have increased the size of the foramen quadratum after the exclusion of the prosquamosal from the lower arch, until the quadrato-jugal was loosened from the quadrate and disappeared in the ligament that represents the inferior arch in the *Lacertilia.*

The *parietal:* The parietal has a broadened horizontal upper portion which unites by strong suture with the frontal, postorbital and the parietal of the opposite side but does not join the postfrontal. The pineal foramen lies in about the middle of this horizontal portion and completely posterior to the orbits. The descending portion of the bone curves sharply outward and downward and joins the quadrato-jugal as described above.

The *squamosal:* The squamosal lies largely on the posterior and inner (toward the median line) side of the parietal. Its lower end is widened and overhangs the distal end of the opisthotic exactly as in the *Sphenodon* but in larger degree. The relations of the parietal and squamosal are rather peculiar; the squamosal forms the posterior side of the parietal arch and reaches almost to the median line of the skull thus forming the major portion of the posterior aspect of the upper part of the skull, in the *Sphenodon* the parietal forms the posterior portion of the skull in the median and does not pass under the squamosal till about the middle of the parietal arch. This gives the squamosal an appearance of greater prominence on the back of the Pelycosaurian skull but the bones have essentially the same relations in both forms.

The cranial region is formed by a single complex bone composed of the closely coössified basioccipital, supraoccipital, exoccipital, opisthotic and petrosal; in none of the specimens are there well defined sutures separating these bones so that they must have united early in life. Figures 2 and 3, Pl. V show this region in specimen 1 where it was found disarticulated and complete; the same region in the other specimens has been somewhat crushed but show enough to make it evident that they are of the same character as specimen 1. The following description is taken from a previous paper discussing specimen 1. (Case, '99.)

"The occipital region closely resembles that of *Sphenodon.* The condyle is formed by the exoccipitals and basioccipital. The exoccipitals meet in the median line above, excluding the supraoccipital from any part in the foramen magnum. Laterally they join the expanded proximal ends of the opisthotics. The supraoccipital is a triangular plate inclined forward as it ascends and joining by the base of the triangle the parietals above. Laterally it joins the opisthotics and inferiorly the exoccipitals. The opisthotics are expanded proximally, joining the supraoccipital and exoccipitals. Distally they are elongated outwards, backwards and downwards. The lower edge of the proximal end is marked by a notch which, in union with similar notches in the basioccipital and petrosal form the fenestra ovalis. The opisthotics remained free during life or until advanced age. This feature is found only in turtles, *Ichthyosaurs* and the young *Sphenodon.* It has been noticed in young lizards before

leaving the egg.* The basioccipital forms the lower portion of the condyle and lies between the exoccipitals and opisthotics. The lower surface is trough-like for its posterior half and supported a posterior extension of the basisphenoid. Laterally a slight notch forms the inner wall of the fenestra ovalis. Anterior to the horizontal, trough-like portion the inferior surface rises sharply; the angle thus formed is marked by a large foramen of unknown function, perhaps the hypophysis passes into the interior of the basioccipital, Pl. V, Fig. 3. The petrosals join the opisthotics, exoccipitals and the basioccipital, but the sutures are not distinguishable. The lower part of the anterior edges were continued forward as long processes, the anterior inferior processes of Siebenrock.† -These are partially destroyed in the specimen. A deep notch in the anterior edge of the petrosals just above the origin of these processes, the *incisura otosphenoidea* Sieb., marks the point of exit from the brain cavity of the fifth pair of nerves (trigeminus). The superior end of the anterior edge is separated from the supraoccipital by a notch which is continued on the sides of the bone as a shallow, short groove. The posterior edge contributes the last portion to the walls of the fenestra ovalis.

"The basisphenoid remained free. The posterior edge is greatly thickened vertically and its lower edge stood well away from the basioccipital. The otic region and the posterior edge of the basisphenoid were covered with a large mass of cartilage. The lower surface of the basisphenoid is excavated by a deep pit, Pl. V, Fig. 4, which opens on the posterior as well as the inferior surface of the bone and divides the posterior into two parts. The upper edge of the posterior surface, forming the base of the pit, was continued backward as a spout-like process articulating with the lower surface of basioccipital. The anterior edge is extended forward as a parasphenoid rostrum originating between the short and stout pterygoid processes.

"The foramina penetrating these bones are remarkably similar in position to those penetrating the same bones in *Sphenodon*. The condylar foramen transmitting the twelfth pair (hypoglossus) penetrates the exoccipital just anterior to the edge of foramen magnum. Its outer end opens in a notch (the *incisura venæ jugularis* Sieb.) in the side of the exoccipital. A little below and further forward a second and much smaller foramen opens in the same notch; this may transmit either the ninth or tenth pair of nerves or a minor blood vessel. Passing forward the notch deepens and is very soon converted into a foramen by the adjacent portion of the opisthotic. This is the *foramen venæ jugularis* of Siebenrock and transmits the jugular vein and either the

*Siebenrock, F.: Das Skelet der Lacerta Simonyi Steind. und der Lacertiden familie überhaupt; Sitzunberichten der kaiserl. Akademie der Wissenschaften in Wien. Mathm. Naturwiss. Classe., ciii, Abth. 1, April, 1894.

†Siebenrock, F.: Zur Osteologie des Hatteria-Kopfes, ibid., Bd. cii, Abth. 1, June, 1893.

ninth or tenth nerves or both of them. In *Sphenodon* the foramen transmits not only these but the twelfth pair as well, the nerves being separated from the vein by very thin walls of bone and may be separated from each other or have a common canal. The opening of the twelfth pair into the notch which forms the beginning of the jugular foramen is then very similar to the condition found in *Sphenodon.*

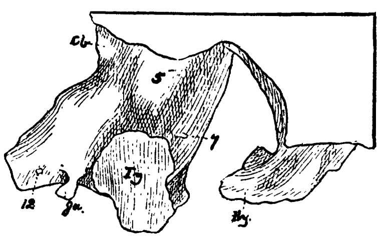

FIG. 1. Lateral view of the cast of the brain cavity of the *Dimetrodon incisivus*, specimen No. 1. *Cb.*, cerebellum; *Ty.*, cast of the otic cavity; *Hy.*, hypophysis; *Ju.*, cast of jugular foramen. 5, 7, 12, casts of the foramina for the corresponding cranial nerves.

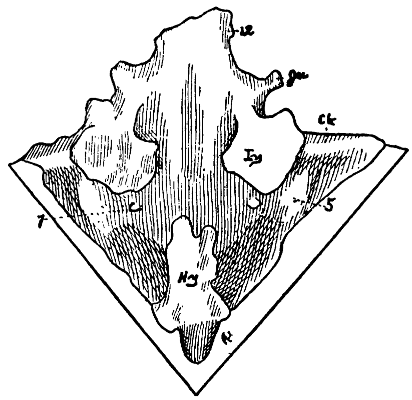

FIG. 2. Inferior view of the same cast. Lettering as in Fig. 1.

"The fenestra ovalis is a single opening leading by a very short canal directly into the brain cavity, a character found in fishes and the amphibian *Menopoma* and existing imperfectly in some recent reptilia, as the turtles. The same thing is described by Cope as existing in another Permian reptile, from the same horizon as the present specimen, but belonging to a separate family, the *Diadectidæ*, and his order *Cotylosauria*.

"The foramina for the seventh (facial) pair of nerves appear on the outer surface of the petrosal just anterior to the fenestra ovalis. They are located relatively a little further back than in *Sphenodon.* On the inner face of the same bone the foramina appear at the side of the base of the brain cavity a little anterior to their external opening. They are located just anterior to a slight ridge which defines the limits of the tympanic cavity. In *Sphenodon* this is about the point of location of a foramen common to the seventh and eighth nerves, which, however, almost immediately divides, the posterior branch penetrating the inner wall of the tympanic cavity and leading the auditory nerve to the inner ear.

"The foramen for the fifth (trigeminus) nerve is completed from the incisura otosphenoidea by the membranous wall of the anterior portion of the brain case, as in *Sphenodon* and many lizards.

"A cast of the brain cavity shows fairly well all parts posterior to the fifth pair of nerves, and the hypophysis anterior to them. As is well known, the brain in the reptilia does not fill the brain cavity, but is supported by a mass of connective tissue carrying lymph and fat masses; so a cast of the brain cavity does not give an exact copy of the brain. However, many points can be brought out by such a cast.

"If the cast be held with the short terminal portion of the medulla horizontal, the lower surface pitches downward at a sharp angle to a point anterior to the tympanic region, and then ascends as sharply to the point of origin of the hypophysis. The superior surface is horizontal and arched from side to side to a point over the tympanic cavity and there turns upward at an angle of 45°. The angle thus produced is marked by a low, narrow ridge running across the cast and marking the position on the brain of a narrow and elevated cerebellum, Fig. 1 *Cb.*, such as occurs in *Sphenodon.* This region was probably the seat of a large amount of connective tissue, and it is probable that the upper surface of the medulla descended at as sharp an angle as the lower. This would make still more marked the resemblance to *Sphenodon* and to the cast figured by Cope. This sharp bend of the medulla downward is not found in other forms, though in the brain of *Chelonia* and some lacertilia a bend is apparent.

"The sides of the medulla show most posteriorly the beginning of the twelfth nerves, Figs. 1 and 2 (12), anterior to these the cast of the jugular foramen, Figs. 1 and 2 *Ju.*, and finally the large casts of the tympanic cavity, Figs. 1 and 2 *Ty.*

"Anterior to the tympanic casts a sharp constriction marks the ridge defining the limits of the tympanic cavity, and then a sharp outswelling the point of exit of the trigeminus nerve, Figs. 1 and 2 (5). Near where these leave the body of the cast a small stub on each side marks the origin of the seventh pair, Figs. 1 and 2 (7).

"The hypophysis is the most interesting feature of the brain. Descending between the anterior inferior process of the petrosal and turning posteriorly, it occupies a small notch in the posterior edge of the upper surface of the basisphenoid and then passes directly into the body of the basioccipital through the foramen mentioned. In the *Crocodilia* a somewhat similar condition exists."

Some additional points have been made out from specimens 1001 and 1002. The distal ends of the opisthotics rest on or close to the upper edges of the quadrates and are overlapped by the squamosals. On the left side of the cranial region of specimen 1002 the median portion of the stapes is preserved; it shows that the stapes was a slender rod extending from the foramen to the quadrate just beneath the opisthotic, unfortunately neither end is preserved. Cope speaks of both a columella auris and a stapes but there is no evidence of more than a single bone in these specimens. The semicircular canals of both sides are fairly well preserved and show the presence of a

large ampullar space (*ampullenraum* Siebenrock) and well developed semicircular canals. A displaced portion of the petrosal shows the penetration of the canals into its body.

The *jugal:* The jugal forms the lower half of the orbital rim. The orbital edge is widened by the development of a strong, sharp ridge on the outer side of the bone so that the socket is bordered on the lower side by a shelf of at least a centimeter in width. The lower part of the bone is very thin and the edges are without thickening rugosities. On the inner side of the jugal a strong ridge extends obliquely downwards and forwards from the orbit to the antero-inferior angle of the bone, here it leaves the

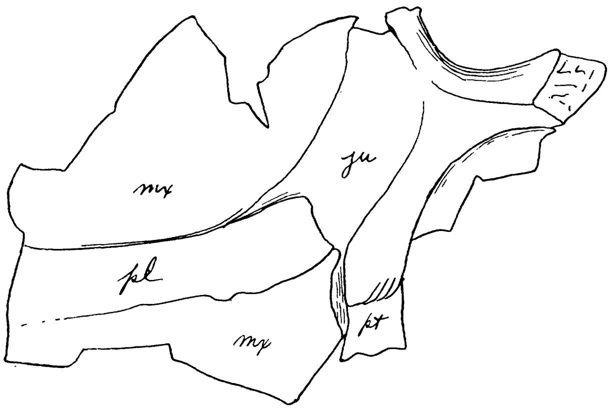

FIG. 3. View of the inner side of the skull opposite the posterior end of the maxillary showing the mode of articulation of jugal, palatine, maxillary and transverse ; *pt.* transverse. Specimen No. 1002.

bone and extends as a sessile process with a bifurcate end ; into the bifurcation of the end articulates the upper end of the transverse, figure 3. The articulation with the maxillary is by a close interdigitating suture which locks the bones very closely together.

The bones of the top of the skull have already been described from specimens number 1 and 114 and the separate elements figured but in the specimen 1001 the top of the skull is preserved on one side without distortion and the bones can be seen in their natural relations. Figures 1 and 1*a*, Pl. VI.

The *postorbital:* The postorbital consists of a flat anterior portion and two posterior branches. One of the posterior branches extends downwards to join the jugal and form the upper half of the posterior rim of the orbit, it passes inside of the jugal and so forms much more of the orbital rim than appears on the exterior. The second, upper, posterior process passes backward to join the prosquamosal and form the upper edge of the inferior temporal vacuity. The anterior portion joins the postfrontal and parietal, its outer edge is thickened and rugose and forms the posterior portion of the superorbital ridge.

The *postfrontal:* The postfrontal is a quadrangular bone which articulates with postorbital and frontal, its outer edge carries forward the rugose superorbital ridge.

The roof of the orbit formed by the postorbital, postfrontal, frontal and prefrontal is rounded and vaulted so that its capacity is much increased inwardly. From the inner edges of the lower side of the postorbital and prefrontal, ridges extend inward in a curve, these are continued inward on the lower surfaces of the frontal and postfrontal until they finally meet on the median line of the skull completing a perfect semicircle. This truss-like ridge surrounding the vaulted roof of the orbit adds greatly to the strength of the skull.

The *lachrymal:* The lachrymal is not well shown in any of the specimens nor is there a lachrymal foramen. In some of the specimens there is evidence of a faint suture on the anterior edge of the orbit indicating the possible presence of a distinct bone but it is impossible to trace the suture out upon the facial portion of the skull. Howse and Swinnerton in their discussion of the development of *Sphenodon* say that there is no trace of a lachrymal in that form, it may be very possible that it did not develop in the *Pelycosauria*, certainly if it did it very early coalesced with the surrounding bones.

The *frontal:* The frontal is an elongate bone lying horizontally in the skull, near the posterior end a process extends outward to the orbital rim forming the middle of the edge. The union of the bones of the two sides gives a distinct cruciform arrangement in the middle of the skull roof. The articulations of the bone are best shown in Figure 1, Pl. VI.

The *prefrontal:* The prefrontal forms the superior anterior angle of the orbit and extends forward between the nasal and frontal above and the maxillary and lachrymal (?) below. The posterior portion of the bone is bent at right angles on the antero-posterior axis, so that the upper portion of the bones is horizontal and the lower vertical. The horizontal portion forms a part of the roof of the skull and the anterior part of the superorbital ridge. On the vertical portion a strong ridge carries forward onto the facial region the superorbital ridge. Beneath the posterior end of this ridge and just anterior to the orbit is a deep pit. The presence of this ridge and pit is one of the characteristic features of the *Pelycosaurian* skull.

The *nasal:* The nasals are elongate bones occupying the median line of the skull and extending from a point just anterior to the orbits to the anterior nares in front.

The *septo-maxillary:* Anterior to the nasal and forming the posterior edge of the narial opening is a singular bone, the septo-maxillary. These bones are of peculiar form, difficult of description, but indicated in figures 1, Pls. II and IV. Each bone

is bent at right angles, so that the lower half forms the floor of the posterior half of the nares and the upper half its posterior edge. The two bones of the opposite side meet in the median line. Of the vertical portion, the inner part is only one-half so high as the outer, so that while the outer part extends to the top of the nares, the inner part reaches up only one-half the height. This forms a dam across the posterior part of the nares, so that the air in entering must first pass upward and over the dam and then downward into the mouth. On the outer side of the septo-maxillary a short

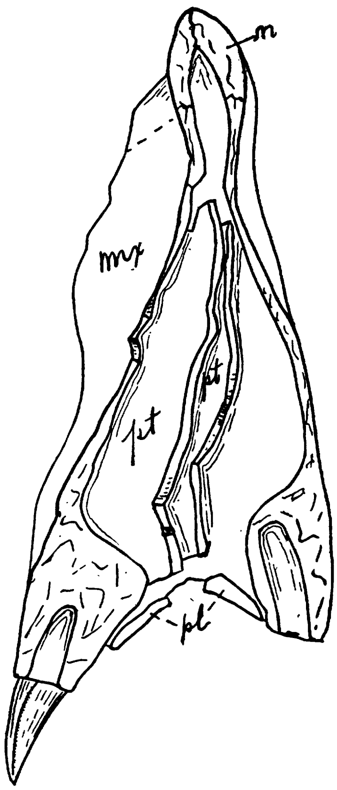

FIG. 4. Cross section through the facial region of the skull of *D. gigas*, No. 1002, opposite the middle of the palate. Showing the thinness of the facial bones and the alveolar edge. *n.*, nasal; *mx.*, maxillary; *pt.*, vertical plates of pterygoids; *pl.*, palatines; *pv.*, prevomer.

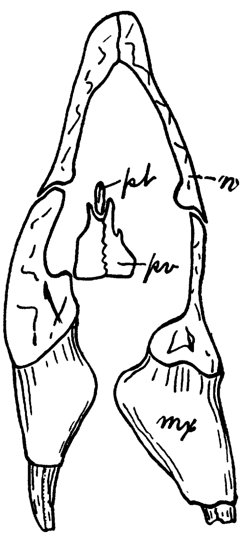

FIG. 5. Section of same opposite the middle of the diastemal notch. Letterings as in Fig. 4.

process at the posterior inferior angle of the nares divides two foramina which pass between the septo-maxillary and the maxillary to the interior of the skull. Their function is entirely problematical.

The *premaxillaries:* The premaxillaries are heavy rounded bones uniting in the median line by a wide sutural area. The lower edge is thickened for the reception of the tooth sockets, and the outer surface of the edge is marked by deep pits and

rugosities. The suture between the premaxillary and maxillary terminates below in the middle of the diastemal notch. Superiorly the premaxillaries send upward and backward long processes, which pass between the nasals and form the upper portion of the nares. The premaxillaries always carry large tusks and smaller teeth; the tusks lie near the median line in the fore part of the bone, but their number seems to be variable in the different species.

The *maxillaries:* The maxillaries are peculiar in their great vertical extent forming the greater portion of the elevated facial region. The upper portion is remarkably thin, never exceeding 2 mm., even in the largest specimen, while the edge of the bone carrying the teeth may reach a thickness of two and three centimeters. The thinness of the upper portion of the maxillary is shared by the adjacent bones, the nasals, prefrontal, jugal and lachrymal; so that this part of the skull is almost always shattered in the processes of fossilization and lost. Specimen 1002 is the only one I know in which the facial region is perfect. The lower edge of the bone is very abruptly widened into a thick dentigerous border, Figs. 4 and 5, which is in strong contrast to the weak upper portion of the facial region. The width of this border is greatest opposite the enlarged canine near the anterior end of the maxillary and decreases in width toward the posterior end of the bone as the teeth become smaller. In the diastemal notch there seems to be no great widening of the edge, even in the forms where teeth are present in the notch. The posterior end of the bone articulates with the jugal, as described above. The outer surface of the bone on the lower edge is marked with pits and rugosities.

The teeth are lenticular in form with distinct fore and aft cutting edges which are strongly serrate. The roots of the teeth are implanted in distinct sockets which may reach a depth as great as the length of the tooth beyond the outer edge of the bone; the outer edge of the bone extends much farther down than the inner so that a good bit of the length of the tooth after it leaves the socket rests against this edge. The root of the tooth is hollow and its inner end is open so that it is evident that the teeth were replaced by absorption of the root and continued growth of new teeth; this process is seen in actual progress in some places. In specimen 114 there are two large canines in the maxillary and in the others but one, this is possibly a case of where one canine has failed to fall out as the other develops. The number of maxillary teeth is variable but does not exceed twenty in any of the specimens. Teeth develop in the diastemal arch in some forms of the *Pelycosauria* and not in others, but this seems to be a developmental feature, as teeth occur in the more primitive *Diopeus*, in the notch but are absent in *Dimetrodon* and *Naosaurus*, the most specialized.

The *transverse:* Heretofore the transverse has not been recognized in any specimen but in numbers 1001 and 1002 its presence and relations are readily seen. On the inner side of the jugal as described above and shown in figure 3 a strong ridge extends forward and receives into its bifurcated end the upper end of the transverse, from this point the transverse extends straight downward on the anterior and outer face of the outer process of the pterygoid; its lower edge fuses with the pterygoid so that it is impossible to describe its lower limit exactly but it does not extend very far down on the pterygoid. The anterior edge of the transverse unites with the posterior end of the maxillary so that it is held firmly in its position.

The *pterygoid:* The pterygoid as repeatedly described has a distinct tripartite form, consisting of an anterior horizontal portion, a median vertical process and a posterior portion which joins the quadrate. The form of the bone is best shown in figures 6 and 7, Pl. V, which are from specimen 1.

The anterior plate is separated from the maxillary by the palatine and the transverse, the bones join the pterygoid directly so that there are no palatine vacuities in the posterior part of the palate. The anterior processes come very close together in the median line but it is impossible to say whether they are united throughout their length or not; it seems probable that there was a space between the posterior portions but the anterior parts come close together. From the inner edges of the anterior portions of the pterygoids vertical plates extend upward in the skull forming a median septum in the lower part of the nasal region. Anteriorly these plates unite and below they pass into the prevomers; the suture between the plates and prevomers is visible anteriorly but posteriorly it disappears. (Figs. 4 and 5, and Pl. IV, Fig. 1, pt.) Similar vertical plates on the inner edge of the pterygoids of *Proterosuchus fergusi* Broom. See Fig. 7*a*, page 26. The median portions of the anterior processes were covered with small teeth that were in part, at least, implanted in shallow sockets.

The median external process is a stout projection with a flat external face which formed a buttress for the lower jaw such as occurs in the *Crocodilia* and in *Sphenodon;* it stands much nearer the surface of the skull than in the forms mentioned so that its outer face is in almost the same plane as the side of the skull. The upper and anterior portion of the external face of this process is certainly formed by the transverse and it is marked by a sculpture of fine lines. The lower edge of the process is rounded and carries a row of teeth in sockets; the number and size of these teeth vary and so seem to be of value in specific determination.

The posterior process is a broad plate standing nearly vertically in the skull but inclining inward somewhat at the top. At the point of departure from the median process it is of less vertical extent and stouter but as it passes back it becomes very

thin and plate-like. It joins the quadrate as described above and from its upper surface rises the epipterygoid.

The *epipterygoid:* The epipterygoid is the only bone that does not have a complete representation in one of the four skulls. In number 1002 the lower ends are still in contact with the pterygoid but the upper part is lost, it seems that the bone articulated loosely by the intervention of cartilage much as in *Sphenodon.* The form was that of a slender flattened pillar.

The *palatine:* The palatines are slender plates closely attached to both the maxillaries and pterygoids. The attachment to the maxillary is very firm, a vertical expansion of the bone is applied to the inner side of the alveolar edge and from this springs the horizontal plate. The bone reaches from the posterior end of the maxillary to a point opposite the canine tooth. The anterior end forms the posterior edge of the posterior nares.

The *basi-sphenoid:* The form of the basi-sphenoid is best shown in figures 4 and 5, Pl. V, the posterior end is swollen and articulates with the basi-occipital; there is evidence of the presence of considerable cartilage in this region during life. On the lower surface there is a deep pit and near the anterior end two strong articular faces. The anterior end terminates in a strong, median, vertical plate.

The deep pit excavating the lower surface of the basisphenoid is in all probability the lower opening of the eustachian tubes. In most reptilian forms the tubes pass into the pharynx in the neigborhood of the basioccipital-basisphenoid suture and anterior to the fenestra ovalis. In the crocodilia and the aglossal batrachians they have a common opening into the mouth. In the present form the tubes probably penetrated the large mass of cartilage covering the otic region and the posterior end of the basisphenoid and found a common opening in the deep pit described. It is difficult to imagine the use of such an extensive cavity in the basisphenoid, but in the *Teleosauria* an equally large cavity is found roofed over with bone. Anterior to this pit two foramina penetrate the lower surface of the basisphenoid bone and on its upper surface a large foramen appears just posterior to the origin of the parasphenoid rostrum. Through the pair on the lower surface the internal carotid arteries enter the bone and through the upper it gains access to the brain cavity by way of the pituitary fossa. On either side of the single foramen a pair of small foramina carry branches of the internal carotid. All of these foramina are very similar in position to the same ones in *Sphenodon.*

The two articular faces near the anterior end are the basipterygoid processes; there are no corresponding articular faces on the pterygoid and it is evident from the specimen 1002 where the bones of the palatal surface of the skull are little disturbed

that they did not articulate with the pterygoids on their inner side opposite the external processes, as at first supposed, but much further back. It is probable that there was a large mass of cartilage between the basipterygoid processes and the pterygoid comparable to the *meniscus pterygoideus* described by Howse and Swinnerton in the developing *Sphenodon* skull.

The *parasphenoid:* From between the basipterygoid process extends anteriorly a vertical, compressed plate (Fig. 2, Pl. VII, and Figs. 4 and 5, Pl. V) which extends directly upward in the median line of the skull. The point of union of this plate and the basisphenoid is marked on the upper edge by a deep notch. It has been shown by Parker, Siebenrock, Howse and Swinnerton and others that the basisphenoid of the adult reptiles is a compound bone formed of the true cartilaginous basisphenoid and a dermal ossification which is the parasphenoid of the amphibians. In embryonic and even in early postembryonic life in *Sphenodon* (according to Siebenrock) the suture between the two is traceable. In the forms with a cartilaginous interorbital septum (*Crocodilia, Lacertilia* and *Chelonia*) the cartilaginous presphenoid is not ossified and the parasphenoid extends as a slender styliform process from the anterior end of the basisphenoid beneath the cartilaginous interorbital septum and supports in embryonic life the membranous floor of the pituitary space. There is no doubt that the anterior process of the basisphenoid in the *Pelycosauria,* as in the *Lacertilia* and *Rhyncocephalia vera,* is the remnant of the parasphenoid united to the basisphenoid and not the presphenoid as first described by Baur and Case ('99).

The *ethmoid:* Instead, however, of the parasphenoid process of the *Pelycosauria* ending as a slender rod in the floor of the pituitary space it extends upward as a strong slender plate and unites above with a second plate which is in contact with the lower surface of the frontal bones. The suture between the parasphenoid and this plate is closed but its position is marked by a low ridge showing the point of coosification. The upper edge of the upper plate is planted firmly against the under side of the frontals and there seems to be ample evidence of a direct sutural union but as the region is somewhat crushed it is possible that the plate did not quite touch the frontal in life but was connected with it by cartilage and that it has been forced into close contact by the accidents of fossilization; however it may be, the relations of the bone would not be altered. The anterior edge of the plate is irregular and very thin showing that it passed gradually into the cartilage of the interorbital septum in front. The upper portion of the posterior edge is thin but the inferior posterior angle is thickened and rounded, there is a deep notch between this angle and the parasphenoid below and this notch marks the position of the escape of the second pair of cranial nerves. There is no trace of either orbito- or ali-sphenoid ossification, as remarked above.

A plate identical in position and relations with this one has recently (Broom, '04) been demonstrated in *Lystrosaurus* (*Ptychognathus*), see Fig. 6. In the *Crocodilia*, *Lacertilia* and *Chelonia* the interorbital septum is cartilaginous, and in the *Ophidia* the osseous septum is formed in a very different manner, by the extension of the brain case forward and the downward development of the frontal bones to meet the parasphenoid without any intervening ossification of a median septum.

In the young *Sphenodon* there is a very complete cartilaginous septum which is double in the region of the nasal and oral capsules, but in the orbital region is single and reaches upward toward the frontal, from the upper surface of the parasphenoid. This plate is called by Howse and Swinnerton the presphenoid cartilage, but the presphenoid is a basi-cranial bone, and in the chondrocranium is that portion of the

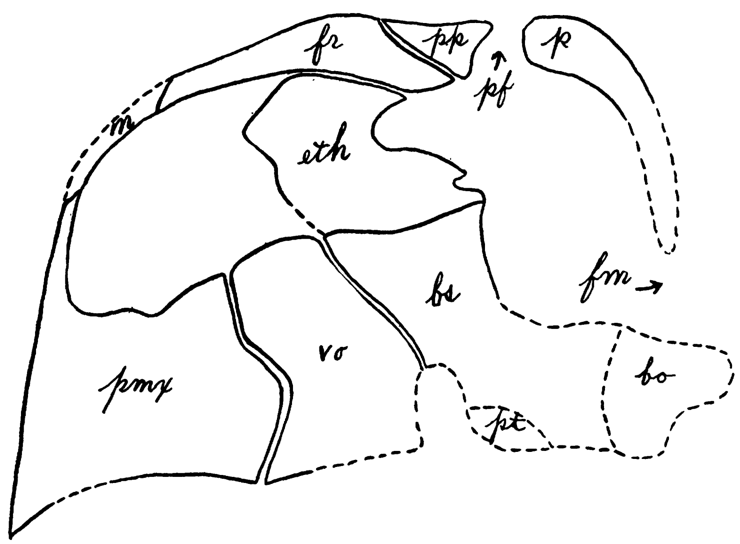

FIG. 6. Median section of the skull of *Lystrosaurus* (*Ptychognathus*) *latirostris* Owen. After Broom. *bo.*, basi-occipital; *bs.*, basi-sphenoid; *eth.*, ethmoid; *fr.*, frontal; *fm.*, foramen magnum; *n.*, nasal; *p.*, parietal; *pp.*, preparietal; *pf.*, pineal foramen, *pmx.*, premaxillary; *pt.*, pterygoid; *vo.*, vomer.

cartilage anterior to the pituitary region. It is evident that the whole of the cartilage called by Howse and Swinnerton the presphenoid cannot be true presphenoid, but that the anterior portion at least must belong to the interorbital septum, the ethmoidal complex.

The developing chondrocranium of the different orders of reptiles is, in all the essentials of the relationships of the parasphenoid bone and presphenoid and septal cartilages, the same; so that it is evident that the median plate of the skull of the *Pelycosauria* here described is an ossification of the median septum of the skull directly connected below with the parasphenoid bone, *i. e.*, the ethmoid.

The *vomers?:* Sutton ('84) and Broom ('02) have demonstrated that the bones known as vomers in the fishes, amphibians and reptiles are not homologous with the bone known as vomer in the mammals, but they are separate ossifications of the palatine region of the skull.

It is impossible to reproduce the argument of Sutton's paper because of its length, but the main points made are as follows: He first shows that the parasphenoid of the adult Pike and the vomer of the human fœtus at birth have essentially the same relations, and that in an earlier stage of the human fœtus, before the roof of the mouth has closed, all the resemblance between the positions of the two bones is even more striking. He shows that in the history of the development of reptiles from amphibians the increased ossification of the basi-cranial bones does away with the need of a well developed parasphenoid bone to support the floor of the brain case. He then demonstrates the complex origin of the maxillary bone in the mammals and comes to the following conclusions:

"It is now evident that for morphological purposes the superior maxillary consists of four distinct portions—

"(*a*) The premaxillary region in relation with the ethmo-vomerine cartilage and the naso-palatine nerve.

"(*b*) A prepalatine portion forming a platform for the support of the anterior end of the vomer.

"(*c*) A maxillary center situate to the inner side of the superior maxillary division of the fifth nerve.

"(*d*) The malar piece lying outside this nerve and supporting the maxillary bone." He concludes that the prepalatine centers are the homologues of the vomers of the amphibians because—

1. They are membrane-formed bones.

2. The bone in each case underlies the anterior end of the vomer and parasphenoid, respectively.

3. Although in the Pike the so-called vomer is median and single, nevertheless in Lepidosteus, Rana, Menobranchus and many other (*reptiles*) forms, the bones so called are double.

4. In their relation to the premaxillæ and palate bones they fulfill the required anatomical conditions.

In his work on the origin of the mammalian vomer Broom ('03), after a careful and full discussion of the relations of the bones, gives the following conclusion, p. 354: "In the large majority of the reptilian orders the so-called "vomers" are undoubtedly homologous with the prevomers of the lizard. This is the case in the Ophidia, Rhyn-

cocephalia, Plesiosauria, Icthyosauria, Pelycosauria, Dinosauria and Pareiasauria. In the Theriodontia and Anomodontia the bone which has been referred to as the vomer is the true homologue of the mammalian vomer, and this is almost certainly also the case in the Chelonia." He then, following the same line of argument, proceeds to demonstrate that the parasphenoid of the *Amphibia* is the homologue of the mammalian vomer.

In comparing the median section of the skull of the *Dimetrodon* with that of *Lystrosaurus* (*Ptychognathus*), Fig. 6, it is evident that the separate vomer of the Anomodont skull is absent in the *Pelycosauria*, but it seems probable that the parasphenoid plate still attached to the anterior end of the basi-sphenoid can be nothing but the developing vomer, thus furnishing ample proof of the theory of the origin of the mammalian vomer as proposed by Sutton and Broom.

Broom has already shown (:03″) that the most primitive of the African forms, *Proterosuchus* of the *Therocephalia*, has a true median vomer (parasphenoid) correlated with vertical plates rising from the inner edge of the pterygoids exactly as in the *Pelycosauria*. This median plate is present in the mammals and in the *Gomphodontia*, it is just as certainly absent in all other reptiles; it seems safe to predict that when the anatomy of the *Theriodonts* is known that a complete series connecting the *Gomphodonts* with the *Therocephalia* will be shown to have this median plate.

The *prevomers:* The specimen number 1002 is of especial value in preserving the thin median plates of the skull. It clearly shows the presence of paired prevomers. The prevomers (Broom :03′) are rather stout rods of bones extending from the middle of the premaxillaries backward and downward in a curve to a point opposite the end of the palatine. Their form and relations are shown in Figs. 1 and 2, Pl. VII, and Fig. 1, Pl. IV. The curvature of the lower surface makes a vaulted roof to the mouth in the anterior portion. In about the middle of their course they are free from the bones on the sides leaving a cavity which forms the posterior nares; the sides of the prevomers at this point are marked by a prominent rugosity of the edge. Superiorly and posteriorly the prevomers join the vertical pterygoid plates; superiorly the upper edges diverge and receive between them the united plates, posteriorly they shade indefinitely into the plates so that it is impossible to fix the exact limits of the bones.

The *lower jaw:* In specimen 1001 the lower jaws are preserved almost perfectly; the coronoid which was a small splint bone seems to be lost from both sides. The posterior portion of the jaw becomes very high by the development of the posterior bones as vertical plates and from the inner side of this region the articular region projects as an almost sessile process made up of various processes from the angular, suran-

gular and prearticular (splenial); for this reason the posterior portion of the jaw is almost always shattered in the ground and the more solid articular region is the most commonly preserved. It was such an isolated mass which was interpreted by Baur and Case as the articular region of the skull.

Figs. 1 and 1*a*, Pl. III, shows the lower jaws and the articular region in detail.

The *articular:* The articular is a flattened disc-like bone completely enclosed on all sides but the superior. The upper surface bears two cotyli corresponding to the condyles of the quadrate. On the under side of the articular the posterior ends of the prearticular (splenial) and the angular meet in the median line and furnish the main support of the articular region; between the articular and angular is slipped the posterior end of the surangular, this appears largely on the upper surface and forms the inner side of the pedicle supporting the articular and its main attachment to the main portion of the jaw. On the outer side of the upper surface the prearticular appears and the articular sends a process forward for a short distance between this bone and the surangular. There is a deep pit extending backward and inward along the line of the articular-surangular suture. From the posterior edge of the articular in specimen 1001 a curious short curved process extends inward and upward.

The main portion of the bone is best understood from figures. The articular pedicle is crushed down, in the natural condition it stood out almost at right angles from the jaw.

The *surangular* passes directly into a broad plate forming the posterior portion of the upper half of the bone; it rises rapidly as it passes forward to meet the rising end of the dentary. There are impressions on the adjoining ends of these two bones indicating the loss of an element, the coronoid.

The *angular* forms the lower portion of the posterior half of the jaw; it is rather wide and continues the lower edge of the jaw as far downward as the coronoid carried the superior edge upward. It extends forward past the middle of the jaw forming a good portion of the outer surface of the jaw.

The *prearticular* extends forward between the angular and surangular till it meets the splenial.

The *splenial* is relatively narrow, covering the upper half of the inner face of the jaw and extending as far forward as the symphasis of the jaw but does not take part in the symphasis.

The *dentary* carries a variable number of teeth in the different species, there are always one or two enlarged tusks near the anterior end, corresponding to the incisor tusks of the premaxillary above but none that correspond to the canine tusk.

It is impossible to pass from the discussion of the skull of the *Pelycosauria* without speaking of its relations to certain of the more primitive reptiles of the African region ; it has been shown in the first part of this paper that there can be no relation as previously supposed between the more specialized African which are ancestral to the Promammalia and the Pelycosauria but there is a group of very primitive forms which show a very decided resemblance to the *Pelycosaurs.*

In the prosecution of his valuable work on the Permian reptiles of South Africa Broom has divided the original group *Theriodontia* into two groups, the Therocephalia and Theriodontia (: 03). These groups are characterized as follows :

THEROCEPHALIA.

" Medium sized reptiles, with temporal region supported by a single lateral arch. Post frontals usually absent (present in Scylacosaurus), postorbitals and squamosals

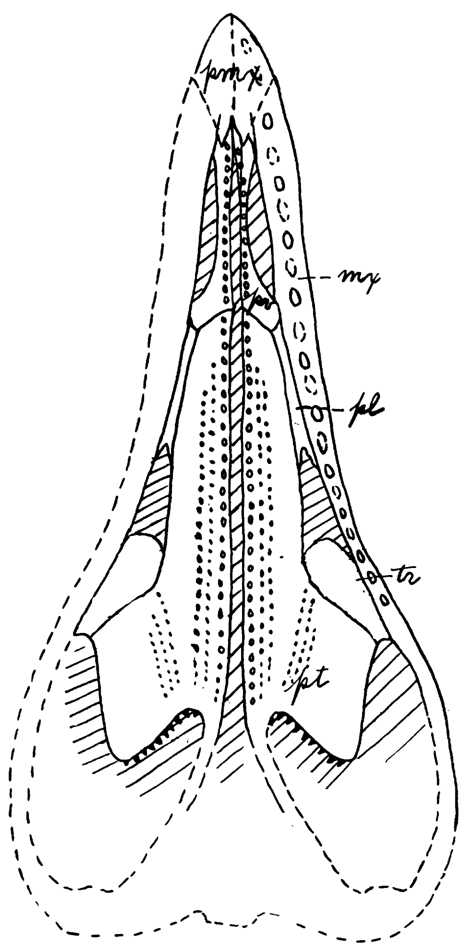

FIG. 7. The palate of *Proterosuchus fergusi*, Broom after Broom.

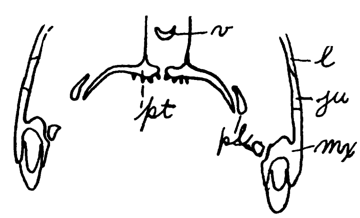

FIG. 7*a*. Cross section through the skull of *P. fergusi* after Broom.

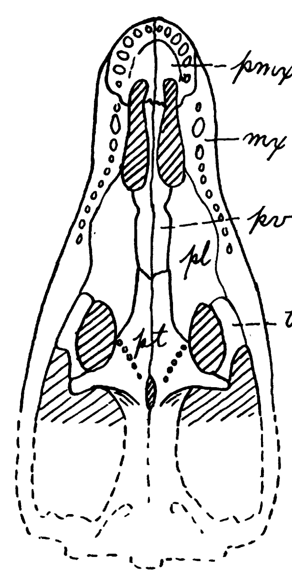

FIG. 8. The palatal region of *Scylacosaurus sclateri*, Broom after Broom.

present, supratemporals and quadrato-jugals absent. A well developed quadrate. Palate a slight modification of the Rhyncocephalian type. Teeth on the pterygoids in Scylacosaurus and Ælurosaurus. Maxillary and premaxillary differentiated as in mammals into incisors, canines and molars. Occasionally more than one pair of canines; molars simple. Scapula without an acromion process; probably a cleithrum. Manus and pes unknown." Including *Scylacosaurus*, *Ælurosaurus*, *Ictidosuchus*, *Deuterosaurus*, *Rhopalodon*, *Titanosuchus*, and *Gorgonops*.

THERIODONTIA.

Medium sized reptiles, with temporal region supported by a single lateral arch. No distinct postfrontals, supratemporals or quadrato-jugals. Quadrate rudimentary. A secondary palate formed by the maxillaries and palatines. Prevomers small. True vomer large. Transpalatines usually absent. Occipital condyle double. No teeth in palate. Scapula with a distinct acromion. Phalangeal formula 2, 3, 3, 3, 3."

Including *Lycosaurus*, *? Cynodraco*, *Cynognathus*, *Galesaurus*, *Gomphognathus*, *Microgomphodon*, *Trirachodon*, and *Diademodon*.

A glance will show the resemblance that, except for the condition of the temporal arches, exists between the *Therocephalia* and the *Pelycosauria*. In Figures 7 and 8 are shown the palate of *Scylacosaurus* and *Proterosuchus* drawn after Broom showing the remarkable similarity of the palate in these genera to the *Pelycosauria*. This resemblance Dr. Broom regards as a common inheritance in the two groups from a Cotylosaurian ancestor, but it is to be observed that the genus *Gorgonops* is the only one in which the condition of the arches is known and in this the temporal region is completely roofed over; the presence of a primitively single arch in the forms otherwise most closely related to the *Pelycosauria* is unknown from observation. Should the genera, *Scylacosaurus*, *Proterosuchus*, *Ælurosaurus* or any of them prove to have an arrangement of the temporal bones indicating the Rhyncocephalian type, even though the temporal vacuities are very poorly developed or even not open the extremely primitive origin of the single arched ancestor of the mammalia as assumed in Osborn's *Synapsida* and *Diapsida* must be subject to some revision.

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Description of Plates.

Plate I.

Fig. 1. Right side of skull of *Dimetrodon* sp. near *incisivus*, Cope. Specimen 1001.

Fig. 1*a*. Explanation. *f.*, frontal ; *ju.*, jugal ; *mx.*, maxillary ; *n.*, nasal ; *orb.*, orbit ; *p.*, parietal ; *ptf.*, postfrontal ; *prf.*, prefrontal ; *pf.*, parietal foramen ; *psq.*, prosquamosal ; *q.*, quadrate ; *q.f.*, quadrate foramen ; *q.j.*, quadrato-jugal.

Plate II.

Fig. 1. Left side of skull of *Dimetrodon gigas*, Cope. Specimen 1002.

Fig. 1*a*. Explanation. Lettering as in Fig. 1*a*, Pl. I. *pmx.*, premaxillary ; *sm.*, septo-maxillary ; *l* ?. lachrymal ; *pt.*, pterygoid.

Plate III.

Fig. 1. Inner side of the left side of the lower jaw of skull shown in Pl. I.

Fig. 2. Outer side of right side of the jaw of same specimen.

Figs. 1*a* and 2*a*. Explanation. *art.*, articular ; *ang.*, angular ; *dent.*, dentary ; *pre-art.*, pre-articular, *sp.*, splenial ; *s. ang.*, surangular.

Plate IV.

Fig. 1. Skull of *Dimetrodon gigas* with the left side removed showing the bones of the median axis. Specimen 1002.

Fig. 1*a*. Explanation. *bo.*, basi-occipital ; *ep.*, epipterygoid ; *mx.*, maxillary of right side ; *n.*, nasal ; *pv.*, prevomer, *pt.*, vertical plates of the pterygoids ; *pl.*, palatine ; *pas.* parasphenoid ; *pt.*, pterygoid ; *pf.*, prefrontal ; *pmx.*, premaxillary ; *sm.*, septo-maxillary ; *v.*, ethmoid.

Plate V.

Fig. 1. Inner side of the quadrate region of specimen 1001. *pt.*, posterior end of pterygoid, *q.*, quadrate ; *q.j.*, quadrato-jugal ; *q.f.*, quadrate foramen.

Fig. 2. Posterior view of the occipital region of specimen 1, *Dimetrodon incisivus*.

Fig. 3. Lower view of the same.

Fig. 4. Lower view of the basi-sphenoid of the same specimen.

Fig. 5. Lateral view of the same.

Fig. 6. Lateral view of the pterygoid of the same specimen.

Fig. 7. Lower view of the pterygoid of the same.

Plate VI.

Fig. 1. Top of the skull of specimen 1001.

Fig. 1*a*. Explanation. Lettering as in Pl. I., Fig. 1*a*.

Fig. 2. Restoration of the skull of *Dimetrodon gigas*. Lettering as in Pl. I.

Plate VII.

Fig. 1. Restoration of the palate of *Dimetrodon gigas*. Specimen 1002.

Fig. 2. Restoration of the median section of the same skull.

Fig. 3. Restoration of the posterior view of the same skull. Lettering of all as in previous figures. *eth.*, ethmoid; *po.*, paroccipital. The arrow of Fig. 2 shows the course of the nares.

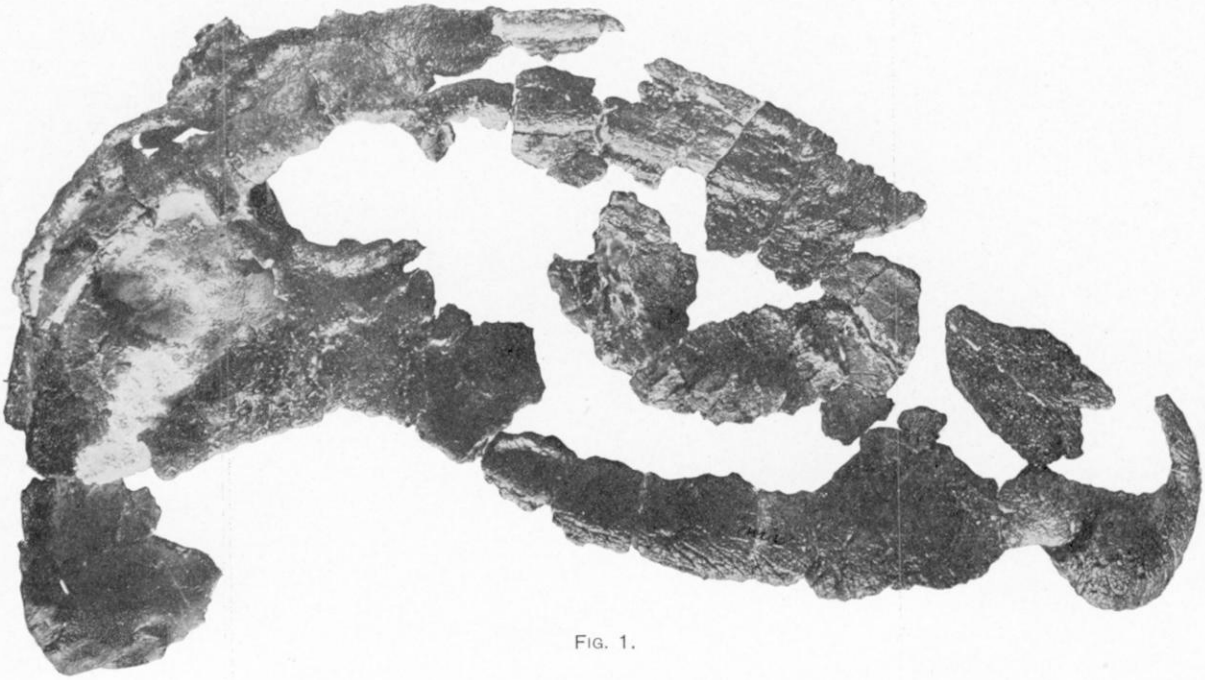

FIG. 1.

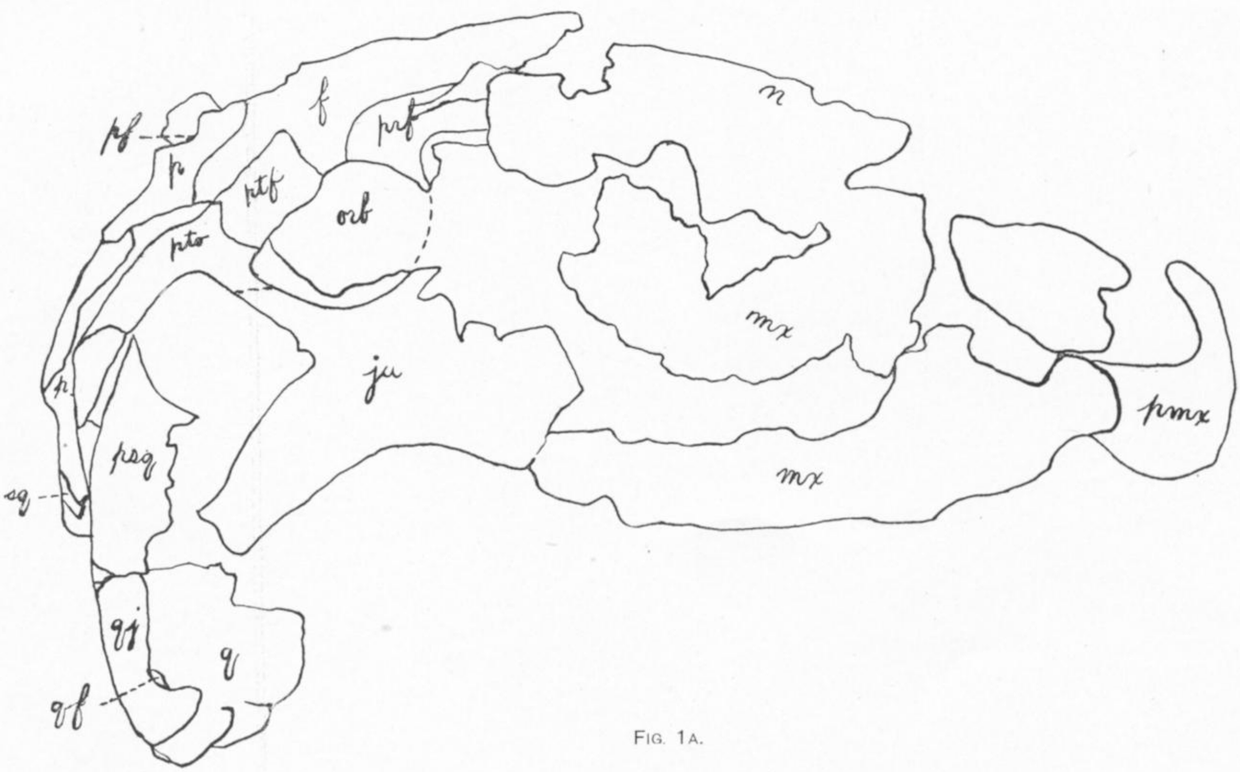

FIG. 1A.

CASE.—MORPHOLOGY OF SKULL OF PELYCOSAURIAN GENUS DIMETRODON.

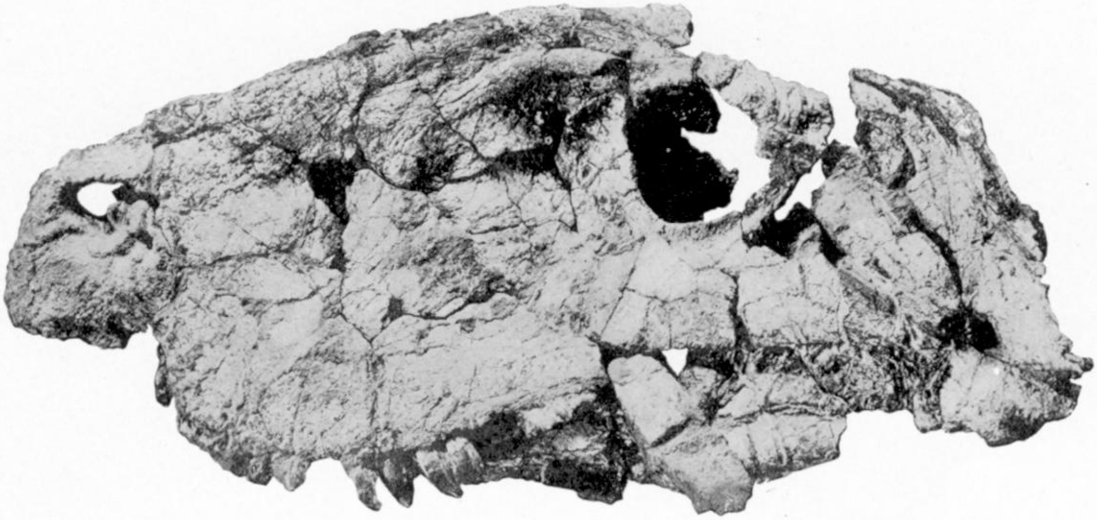

FIG. 1.

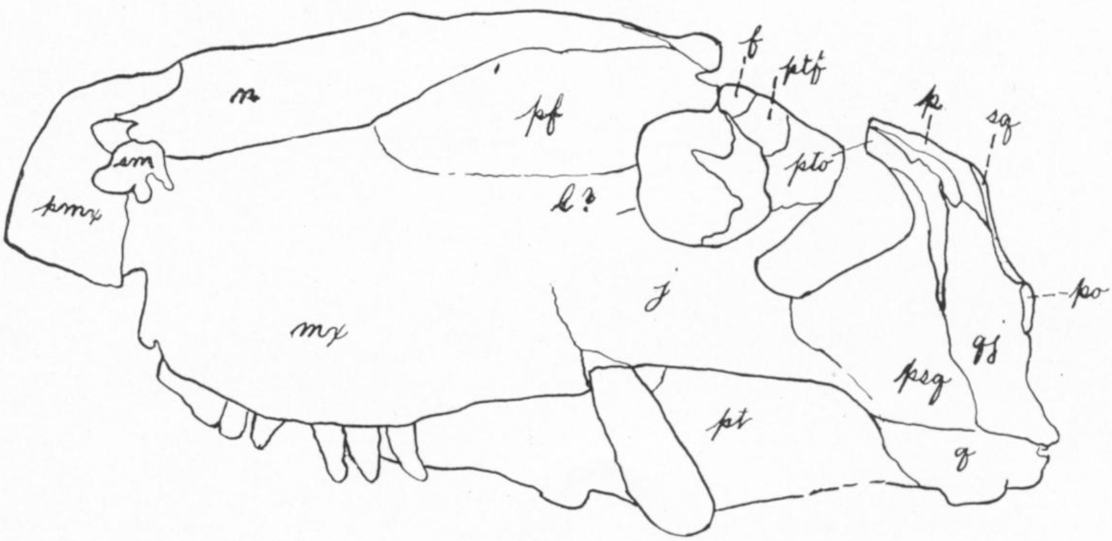

FIG. 1A.

CASE.—MORPHOLOGY OF SKULL OF PELYCOSAURIAN GENUS DIMETRODON.

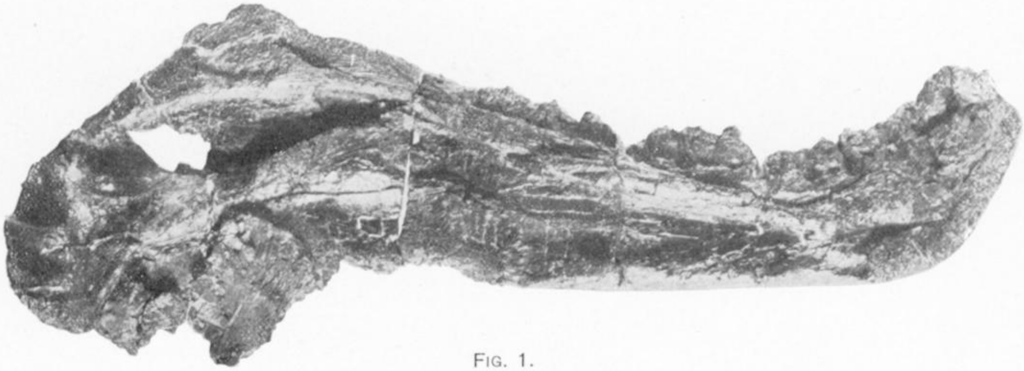

Fig. 1.

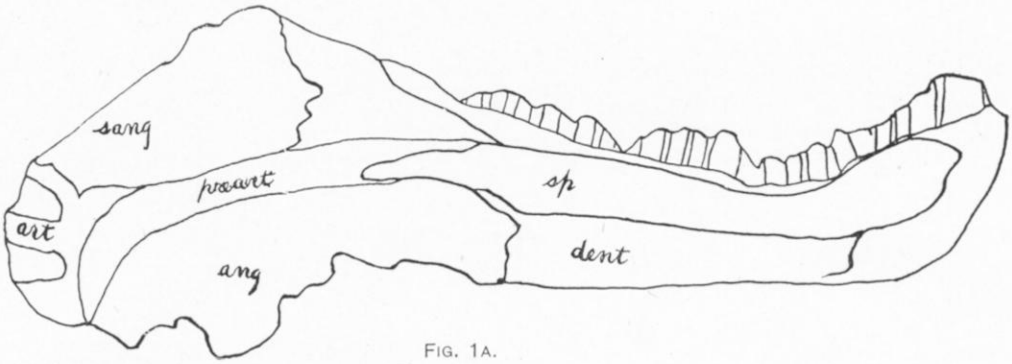

Fig. 1a.

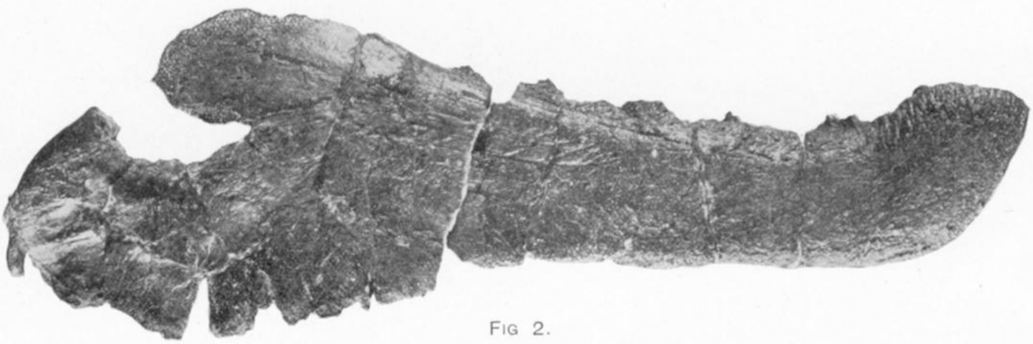

Fig 2.

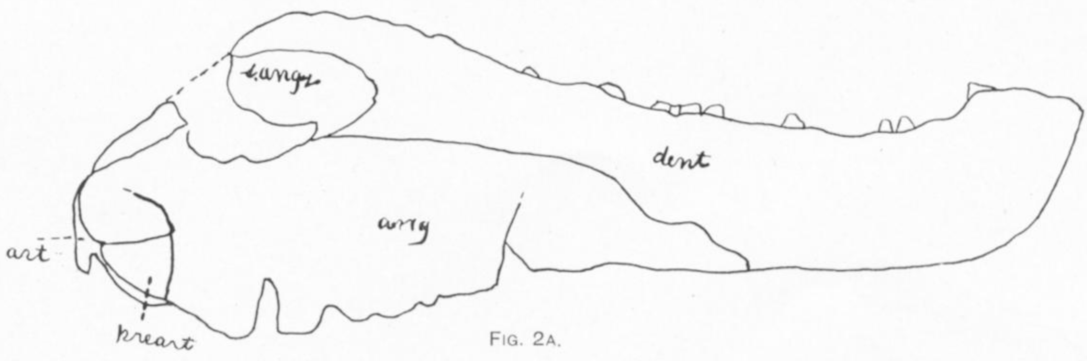

Fig. 2a.

Case.—Morphology of Skull of Pelycosaurian Genus Dimetrodon.

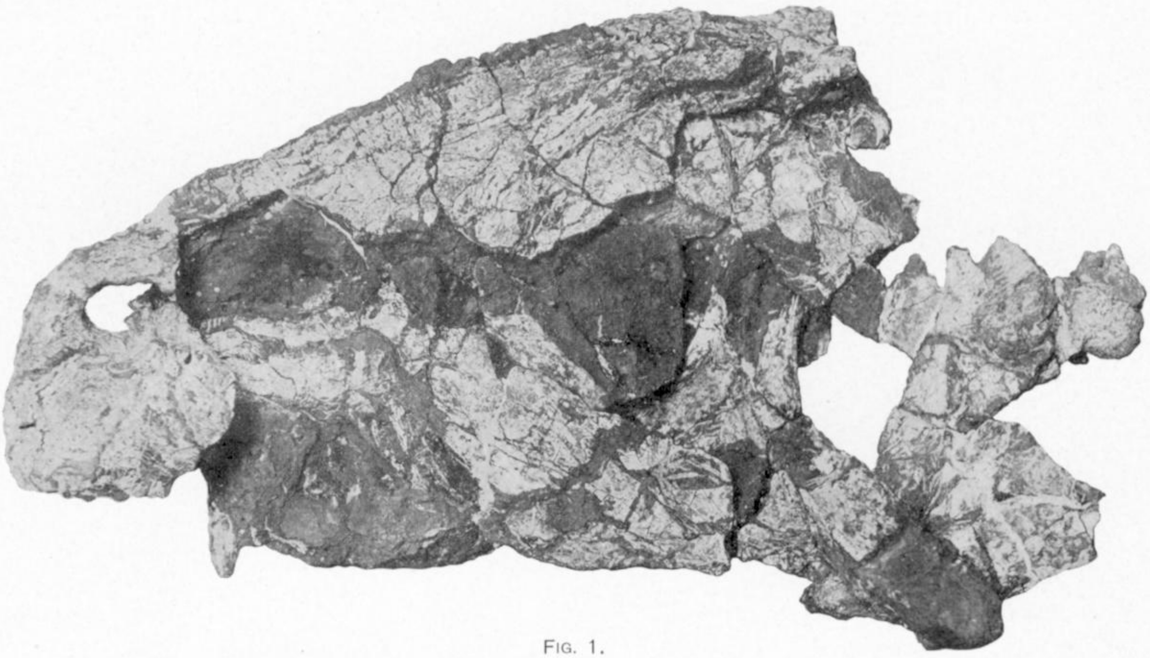

FIG. 1.

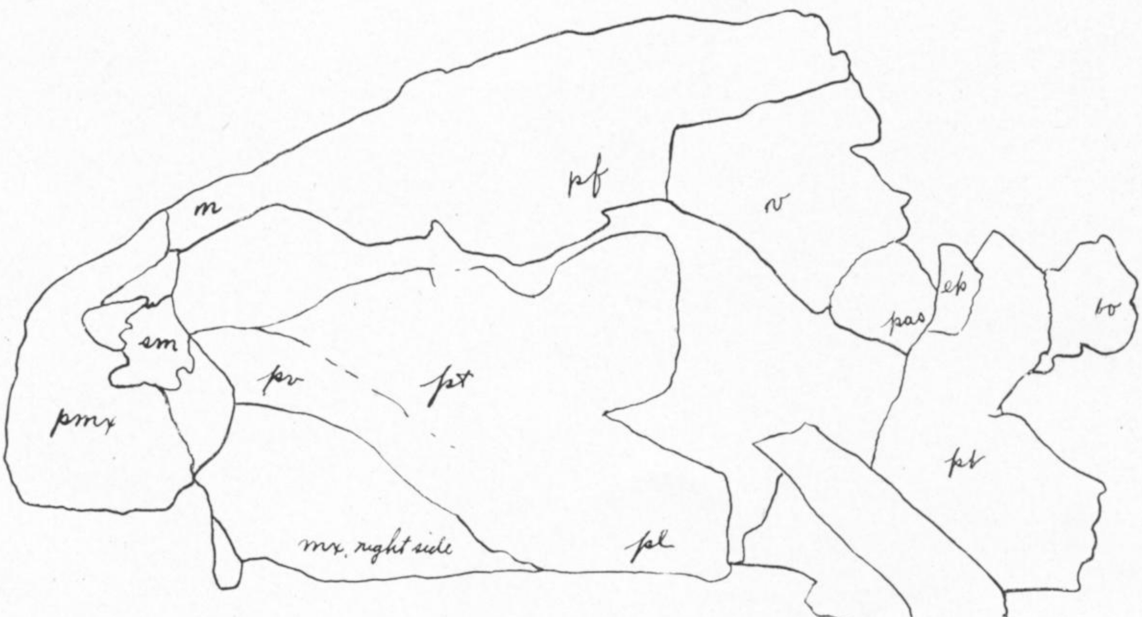

FIG. 1A.

CASE.—MORPHOLOGY OF SCULL OF PELYCOSAURIAN GENUS DIMETRODON.

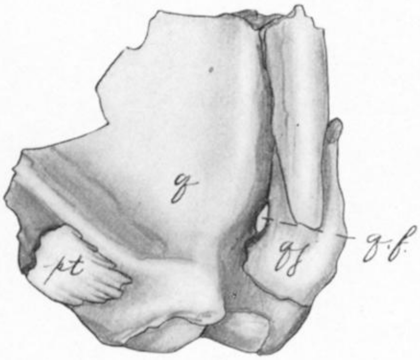

FIG. 1.

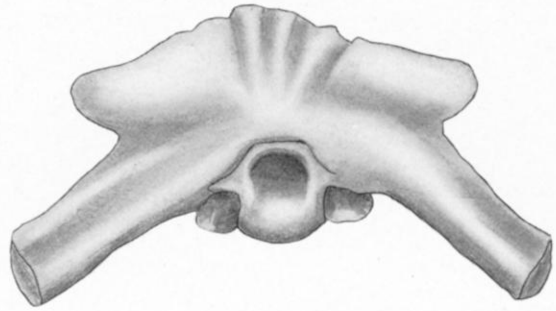

FIG. 2.

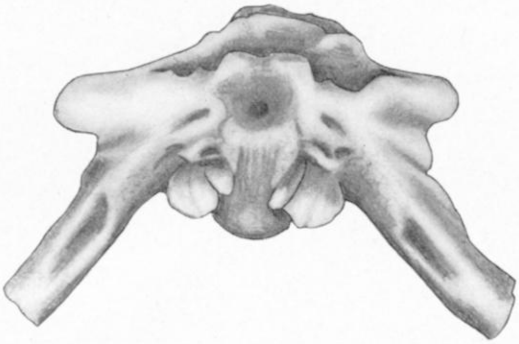

FIG. 3.

FIG. 4.

FIG. 5.

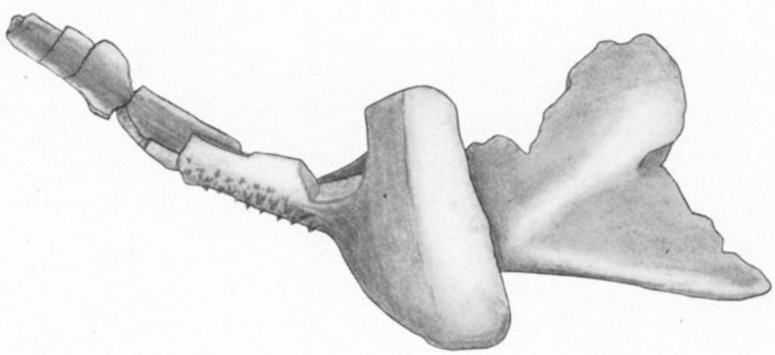

FIG. 6.

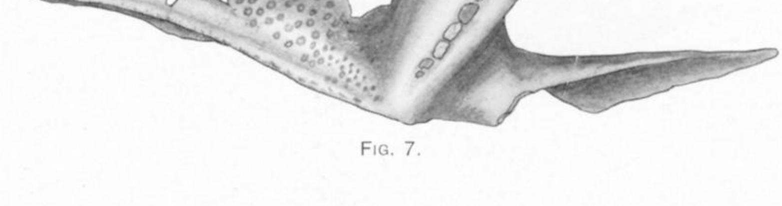

FIG. 7.

CASE.—MORPHOLOGY OF SKULL OF PELYCCSAURIAN GENUS DIMETRODON.

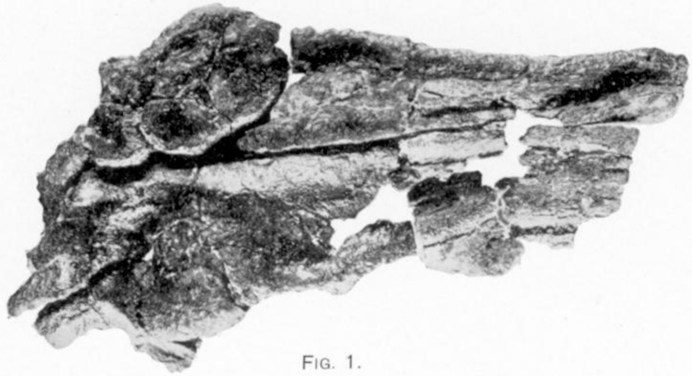

FIG. 1.

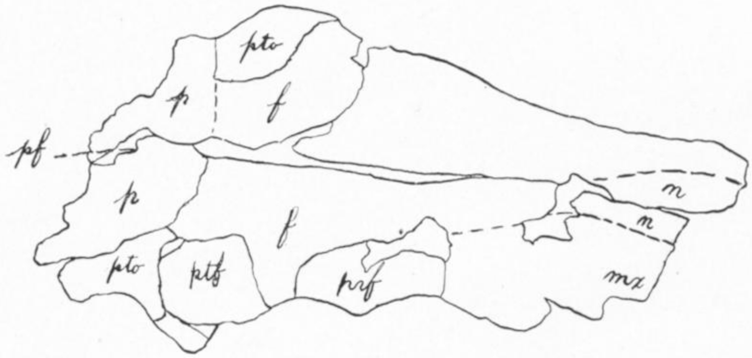

FIG. 1A.

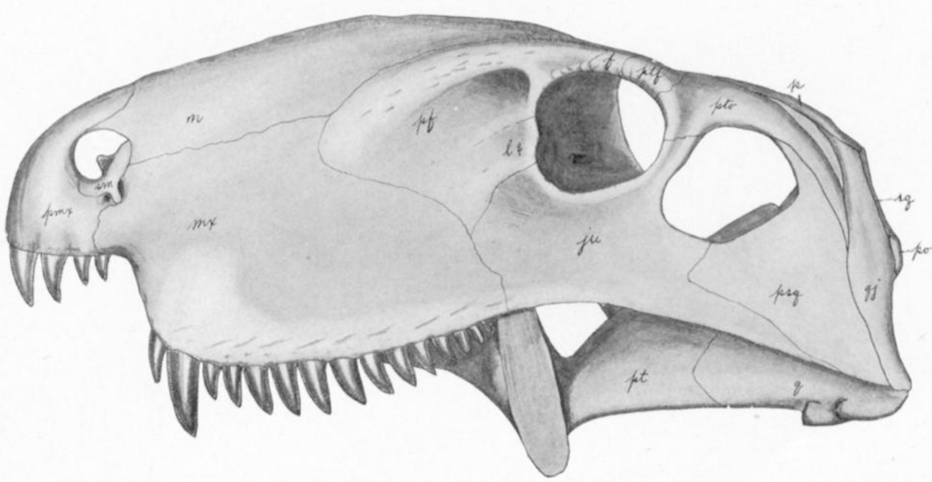

FIG. 2.

CASE.—MORPHOLOGY OF SKULL OF PELYCOSAURIAN GENUS DIMETRODON.

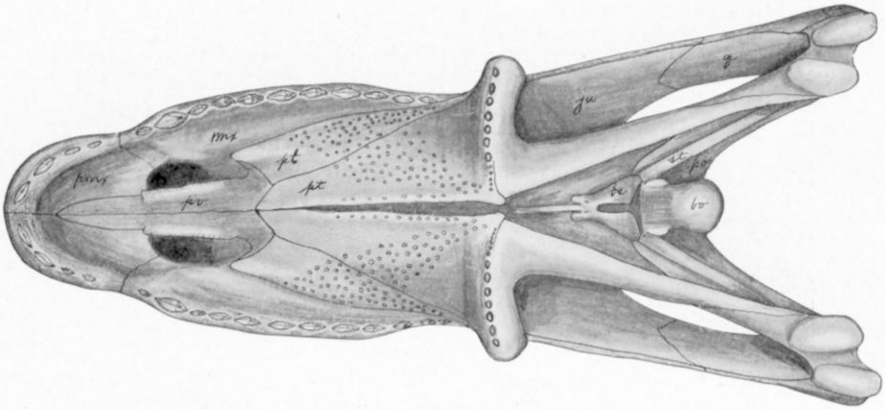

FIG. 1.

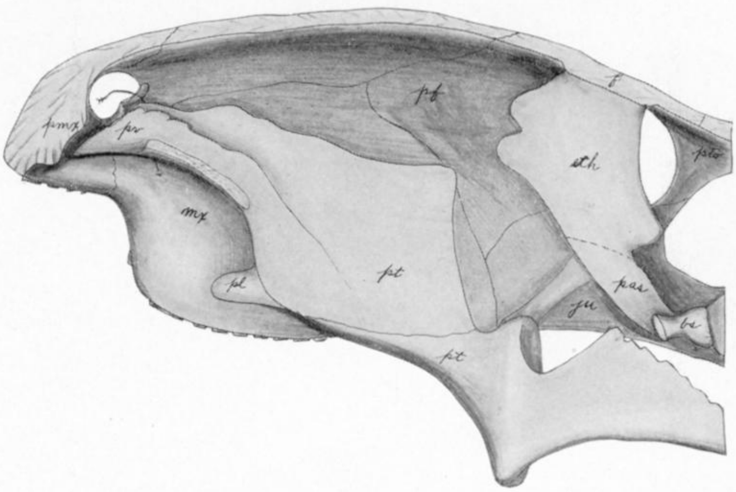

FIG. 2.

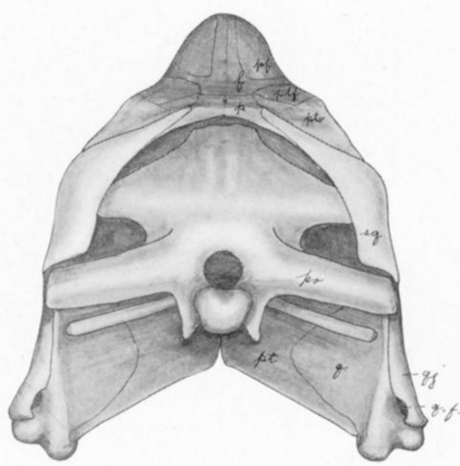

FIG. 3.

CASE.—MORPHOLOGY OF SKULL OF PELYCOSAURIAN GENUS DIMETRODON.